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Title: High-Resolution 3D Acoustic Borehole Integrity Monitoring System

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High-Resolution 3D Acoustic Borehole Integrity Monitoring System

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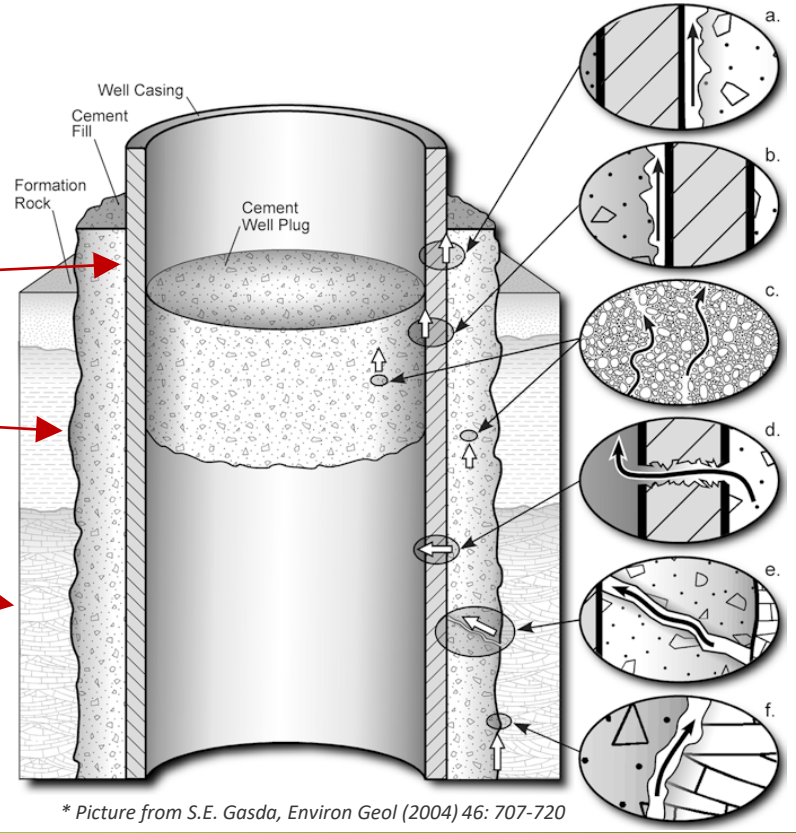
Technical Objectives

- **System development for borehole integrity**
  - Physical process, improved methodology, technique or device.
    - All of the above (Develop a high-resolution 3D imaging **system** for improved wellbore diagnostics and integrity assessment)
  - Expected outcomes and advancement of knowledge
    - Extend applicability to:
      - casing-cement interface
      - cement-formation interface
      - out in the formation



** Picture from S.E. Gasda, Environ Geol (2004) 46: 707-720*

Project Background/Methodology

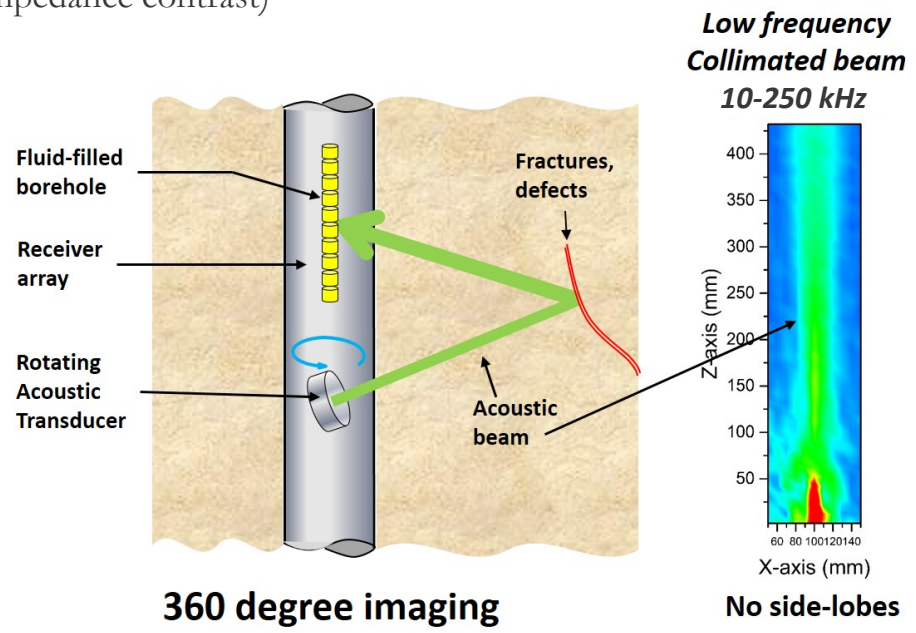
- **Previous supporting research**
  - Project evolved from "Seedling" to "Sapling" to this project
- **Current state-of-the-art**
  - Either sonic probe (low resolution), or ultrasonic probe (low penetration)
- **Project started:**
  - 2017

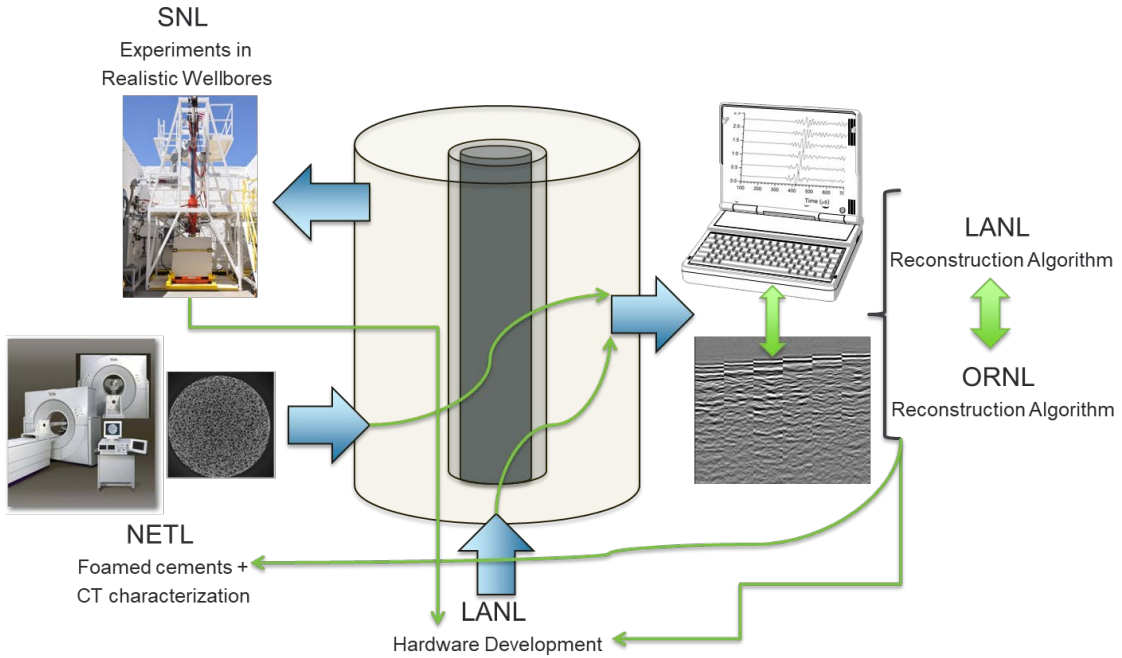
Comparison of existing techniques and the present approach

Method	Frequency (kHz)	Range (m)	Resolution (mm)
Sonic probe	0.3-8	15	~ 300
Present approach	10-150	~ 3	~ 5
Ultrasonic probe	>250	casing	4-5

Project Background/Methodology

- **Methodology**
  - Use simple low-frequency collimated source in conjunction with receiver array to collect data beyond casing
  - Use advanced signal-processing techniques and data inversion to reconstruct images
  - Investigate use of foamed cements viability (conventional methods have difficulty detecting foamed cement due to low impedance contrast)





Technical Approach

Method	Frequency (kHz)	Range (m)	Resolution (mm)
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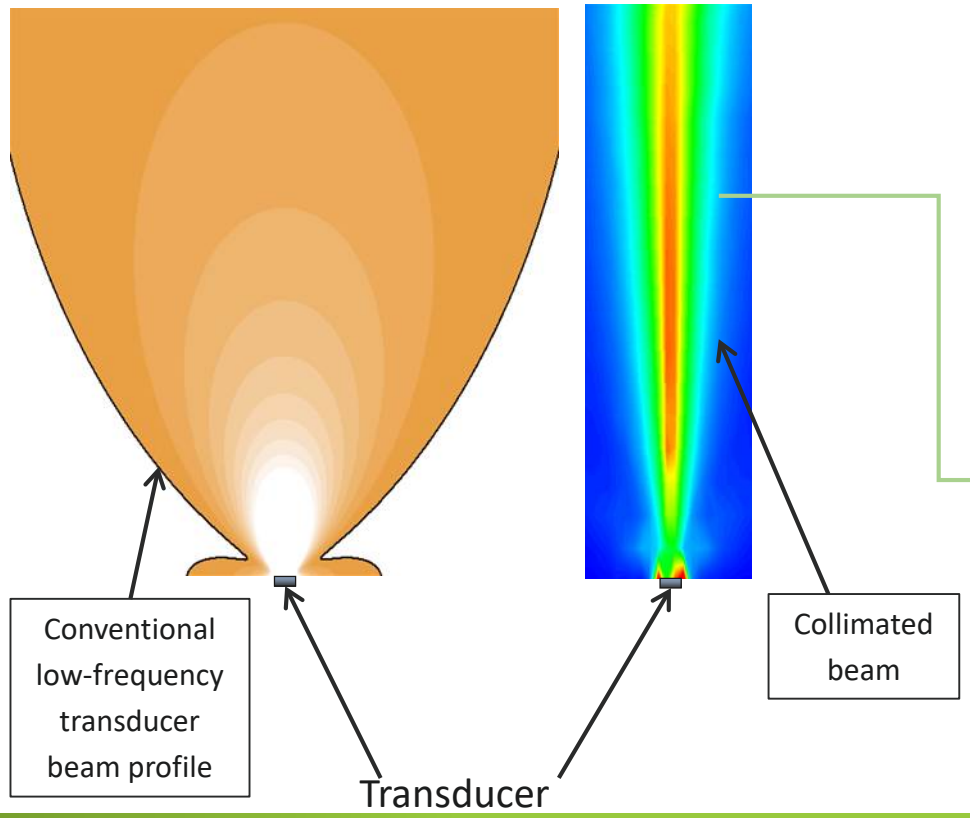
Novel technique that fills technology gap

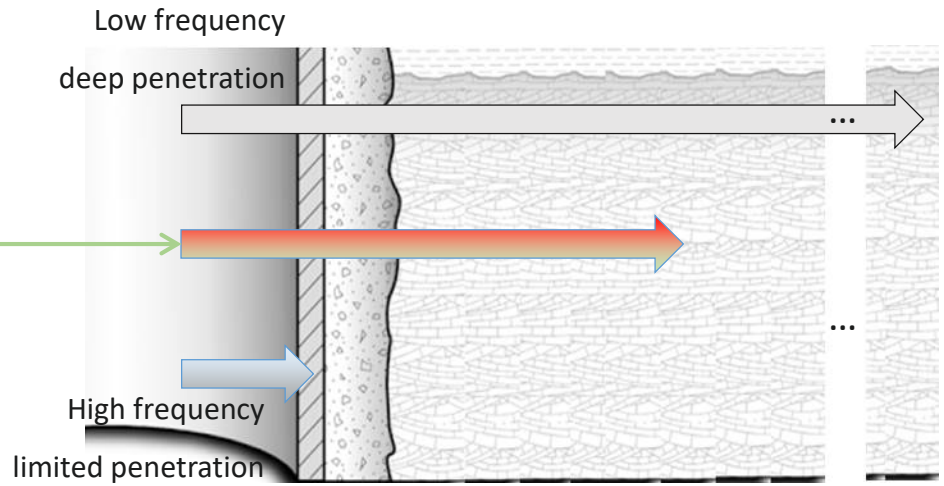
1. Collimated beam for increased resolution



2. Low frequency for deeper penetration

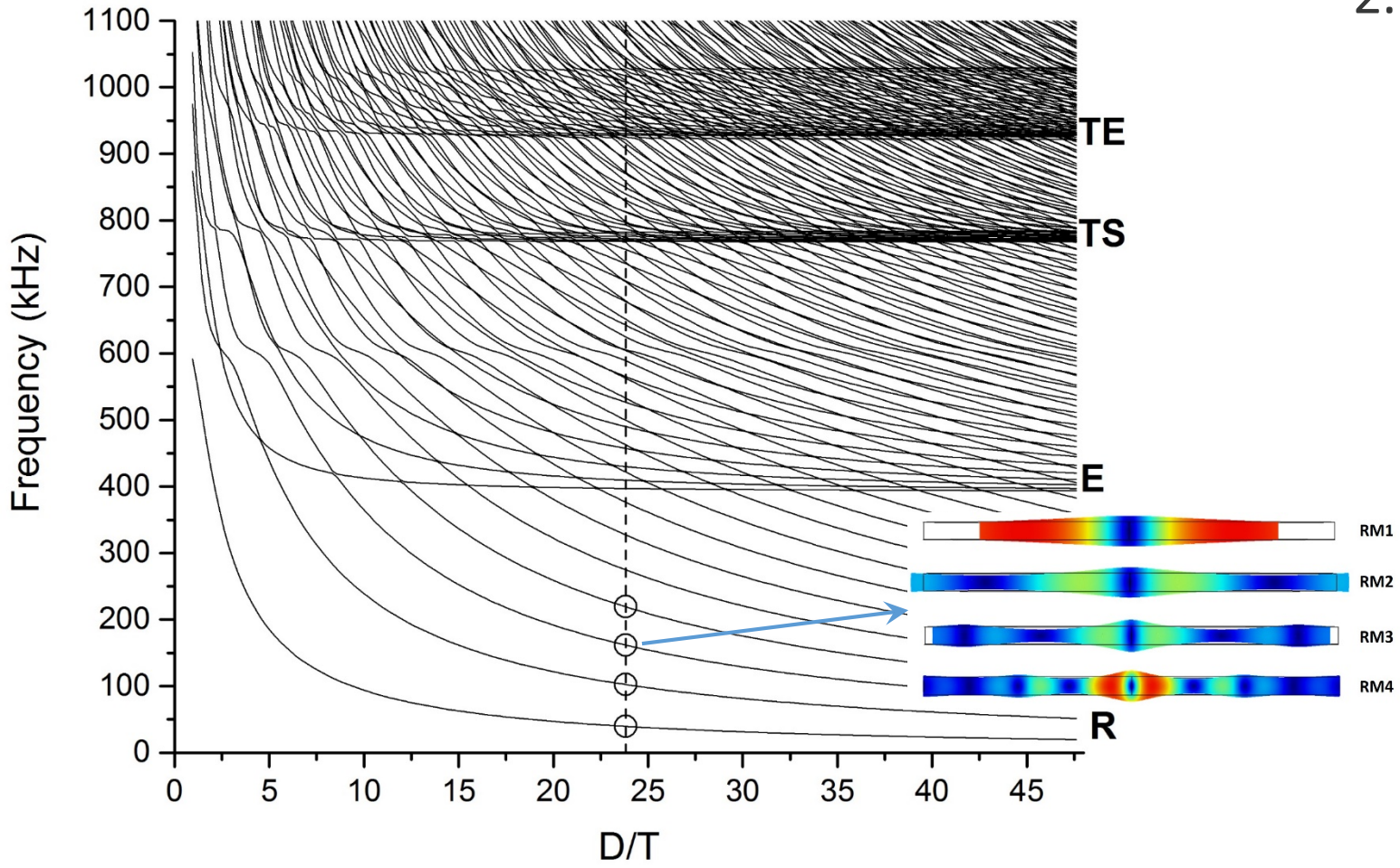
$$Attenuation \sim f^{n}$$

f = frequency, n = 1-2

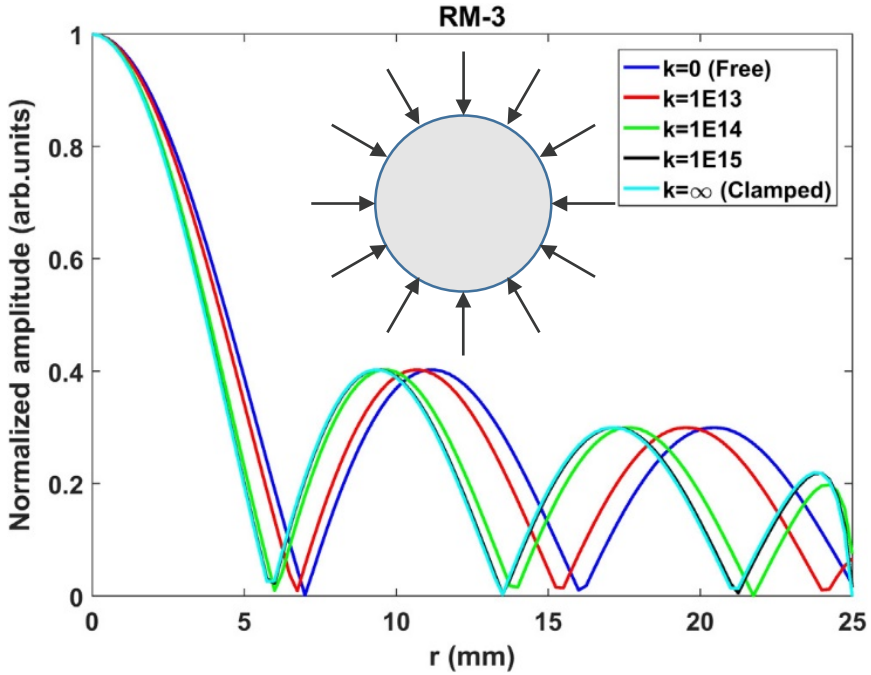


Technical Approach

1. Use radial modes to generate Bessel-like acoustic beams



2. Laterally clamp transducers to alter boundary conditions



Normalized out-of-plane displacement on the surface of the disc for RM-3 for different lateral stiffness k (N/m3)

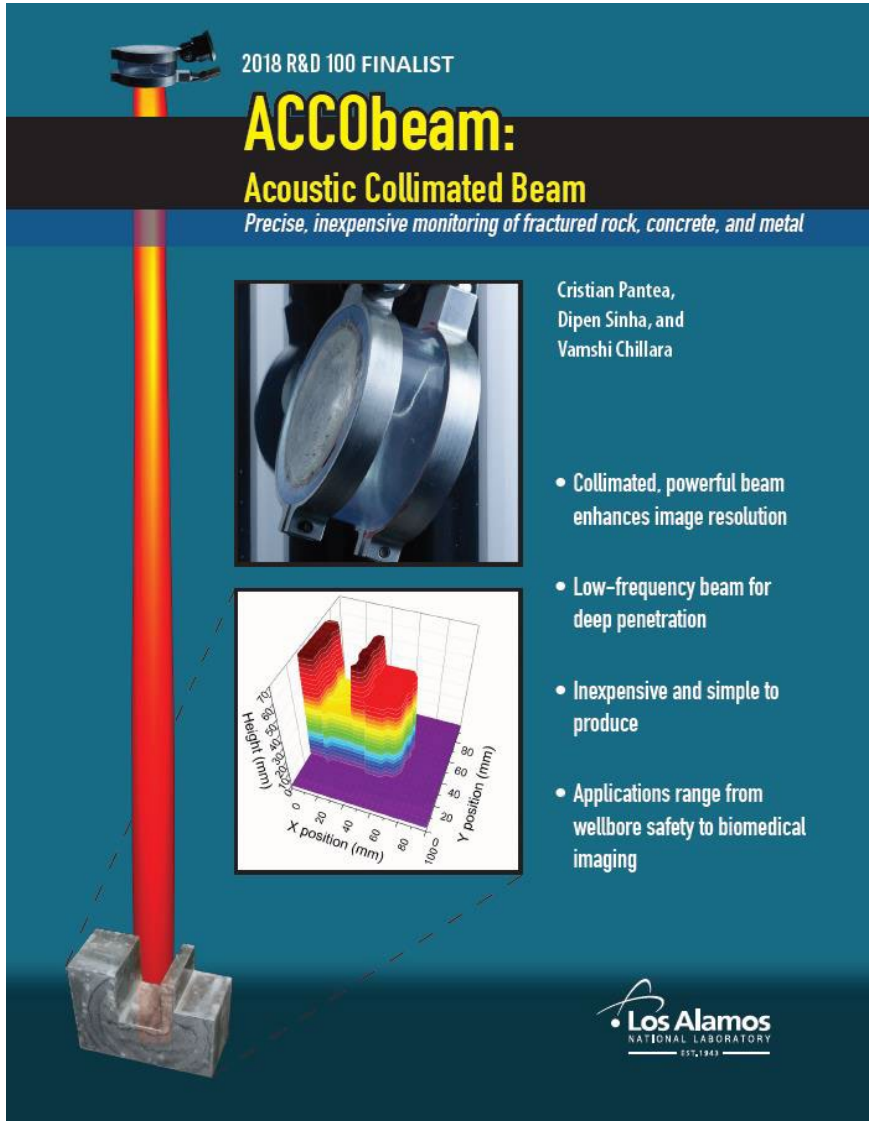
Technical Approach

- **Include telemetry (i.e., details on how data is/will be transmitted)**
  - Data will be transmitted through existing wireline

Accomplishments to Date

- Performed a comprehensive literature/existing technology study for wellbore integrity monitoring tools
- Identified potential partner for further developing the proposed technique
- Refined hardware (ACCObeam – Acoustic Collimated beam)
- Refined software for faster measurement and analysis
- Performed theoretical prediction on foamed cement Young's modulus with different hydration degrees
- Acquired data in granite with embedded defects (wall thinning, casing eccentricity, channeling, delamination)
- Pending data analysis for the above.
- Planning cementation of 4" casing in two samples of Mancos shale

Accomplishments to Date



- Appl. Phys. Lett., 2018, v. 113, issue 7, p. 071903
- Wave Motion, 2018, vol. 76, p. 19-27
- Appl. Phys. Lett., 2017, v. 110, issue 6, p. 064101
- Proceedings of SPIE, 2017, v. 10170, p. 1017024
- 1 manuscript in preparation (sandstone characterization)

- 1 conference paper–Rock Mechanics
- 1 conference paper submitted –Nondestructive Evaluation

- 1 patent application (Resonance-based Nonlinear Source)
- 1 patent application (Bessel-like Acoustic Source)
- 1 provisional patent (Imaging Technique with Low-frequency Beam)

Lessons Learned

- **Describe any challenges and issues that have presented themselves.**
  - Research gaps/challenges.
    - —Engineering issues with hardware packaging for experiments in granite
  - Unanticipated research difficulties.
    - —N/A
  - Technical disappointments.
    - —N/A
  - Changes that should be made next time.
    - —Closer interaction with technical members of the team

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